Space Weather Technical Forecast

Issued on Tuesday, 13 February 2024 at 00:45 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: CME arrivals possible from Day 1 into Day 2 (13-14 Feb), with G1/Minor Storm intervals likely and a chance of G2/Moderate Storms. M-flares expected, with a chance of X-flares. S1/Minor radiation storm likely to slowly decline.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Activity was Moderate with the peak flare M6.5 at 12/0348 UTC, from AR3576 in the southwest. A long period M2.6 flare peaking at 12/2117 UTC was also seen from over the northeast limb. There are seven sunspots on the visible disc. Large region AR3576 continues to be primarily comprised of negative polarity spots, but with a weak delta spot persisting to the north of its main leader. Slow growth has continued in AR3582, with some coalescence in the intermediate spots of AR3583, plus an increase in length. Both these regions have some slight complexity, with a beta-gamma configuration, and hints of a weak delta trying to develop in AR3583. The new region on the northeast limb may be the leader of a larger region, with flare and CME activity evident from over the limb.
Several large and fast CMEs have been observed in the last 24 hours, however none are currently expected to be Earth directed, although analysis is ongoing.

Solar Wind / Geomagnetic Activity: Solar winds as observed by ACE and DSCOVR at L1 showed waning CME influence. Wind speeds were initially elevated, around 550 km/s, but declined to slightly elevated levels near 470 km/s. Density was mostly average or below. The IMF, Bt, was weak at 7nT or below. The north-south component, Bz, varied weakly between +/- 5nT, but was mostly northward directed. Phi angle was mostly negative (towards the Sun), but with brief variations to positive (away from the Sun). Geomagnetic activity was Quiet (Kp 0-2).

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux started the period just below the S1/Minor Radiation Storm level, but rose above S1 soon after 12/0800Z, rising to a peak of 100pfu at 12/2130UTC, which is just touching the S2/Moderate threshold. 100Mev proton flux briefly reached the 1pfu level between 12/1015-1430 UTC, but has since declined to around 0.5pfu.
GOES16 high energy (greater than 2MeV) electron flux remained mostly at background levels. The associated 24-hour fluence was well below the Active (1e8 integrated pfu) threshold on a slight rising trend. The fluence at 13/0000 UTC was 2.6e6 pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate activity is expected with further M-flares, and a chance of X-flares. These most likely from AR3576 in the southwest, or perhaps from the new region rotating onto the northeast limb.

Solar Wind / Geomagnetic Activity: There are three CMEs which may have Earth-directed impacts, two of which are potential glancing blows during Day 1 (13 Feb), with a third more likely arrival late Day 1 into early Day 2 (13-14 Feb), but low confidence in the extent of any impacts. This has the potential to combine with the previous impacts, leading to a risk of enhanced

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response. Solar winds are then expected to gradually ease Day 3 (15 Feb) onward.
Initially Quiet geomagnetic activity is likely. During Day 1 and into early Day 2 with the potential CME arrivals, G1/Minor Storm intervals become likely with a chance of G2/Moderate Storms. Any combined impacts bring a slight chance of G3 Strong Storms. CME influence will then ease later Day 2 into Day 3, with activity becoming mainly Quiet to Unsettled by Day 4 (16 Feb).

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux is currently just below the S2/Moderate Radiation Storm threshold. Further enhancements are possible associated with potential CME arrivals from Day 1 into Day 2 (13-14 Feb), along with any significant flares from AR3576. In the absence of further enhancements, proton flux is most likely to follow a declining trend, likely falling back below the S1 threshold Day 2 into Day 3 (14-15 Feb).
High energy electron flux (greater than 2MeV) and the associated 24-hour electron fluence may rise later in the period after CME effects wane, with just a slight chance of reaching the Active threshold (1e8 integrated pfu).

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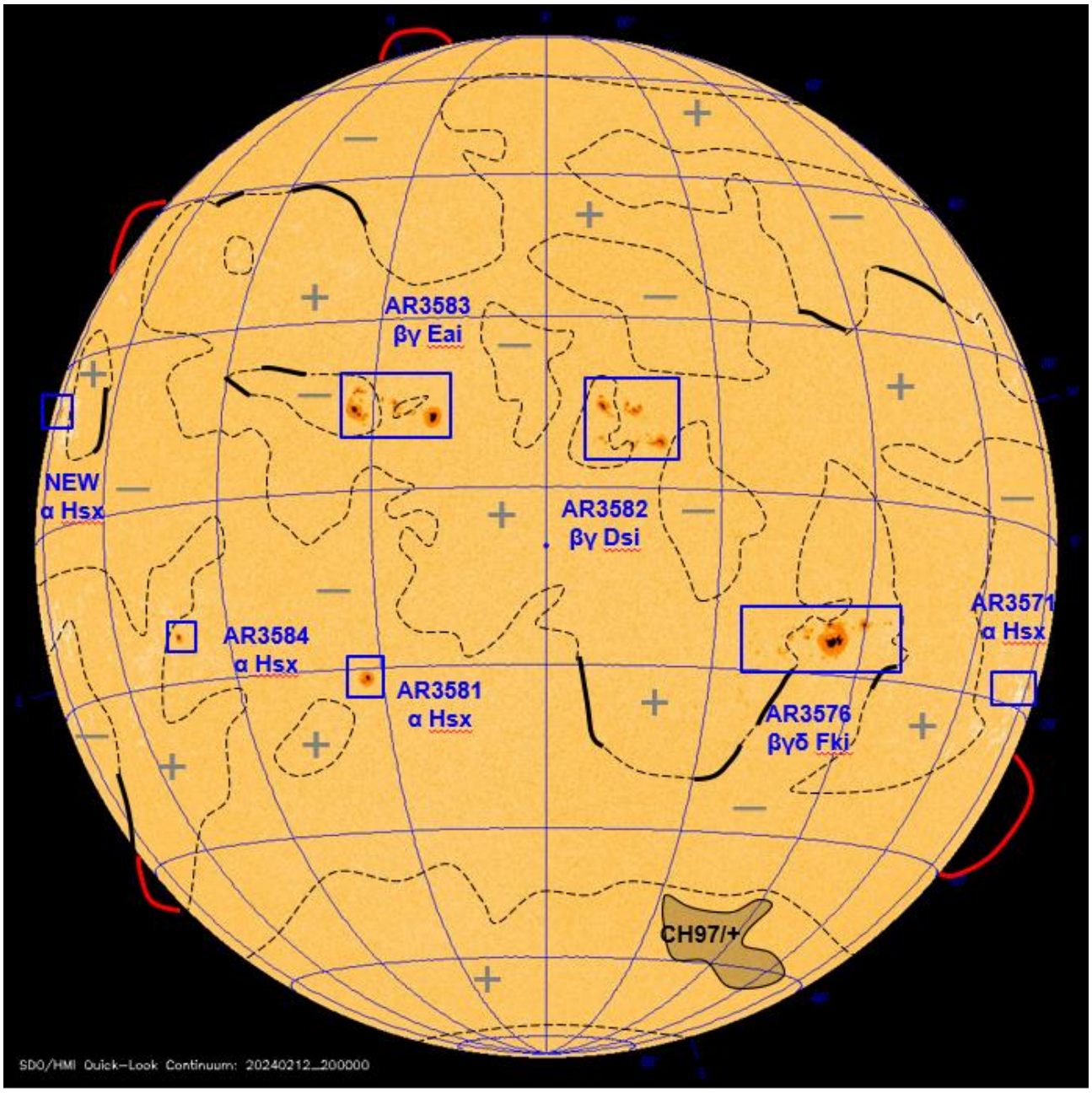
Figure 1. Solar Analysis Valid 12/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are three CMEs which may have Earth-directed impacts, and dominate the geomagnetic forecast for the start of this period. The first is a CME associated with the 08/2030 UTC south-centre filament eruption. This is modelled as crossing 1AU mainly behind and below the Sun-Earth line perhaps early on Day 1 (13 Feb). The second is from the long period C-class flare of AR3579 and an associated filament eruption from 10/0700 UTC. This has been analysed as potentially Earth-directed, possibly arriving during the first half of Day 1 (13 Feb). These two CMEs may also combine to give a single arrival, but confidence in either of them arriving at Earth is low.

The third is from the AR3576 M9.0 flare at 10/2100 UTC. This is a complex eruption near centre disc, resulting in a broad partial halo shock, but with the bulk of the material appearing to be deflected mainly northwest. It is more likely this feature will arrive at Earth, either later on Day 1 (13 Feb) or early Day 2 (14 Feb), however there is low confidence in the extent of any impact, with much of the material directed north and west. Any arrival has the potential to combine with the previous impacts, leading to a risk of enhanced response.

Solar winds are then expected to gradually ease Day 3 (15 Feb) onward, and with CH97/+ to the far south, no coronal hole enhancements are expected in this period.

Initially Quiet geomagnetic activity is likely. During Day 1 and into early Day 2 with the potential CME arrivals, G1/Minor Storm intervals become likely with a chance of G2/Moderate Storms. Any combined impacts bring a slight chance of G3 Strong Storms. CME influence will then ease later Day 2 into Day 3, with activity becoming mainly Quiet to Unsettled by Day 4 (16 Feb).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	70	40	5	1
Strong	G3	No	15	10	1	1
Severe	G4	No	2	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
09/0113	Nil	Filament	S-centre	641 km/s	Early 13 Feb	Glancing blow possible
10/1040	Nil	Filament/C-flare AR3576	S-centre	890 km/s	Early 13 Feb	Glancing blow possible
11/0330	Partial shock	AR3576	SW but directed NW	810 km/s	Late 13 Feb	Complex eruption – low confidence impacts

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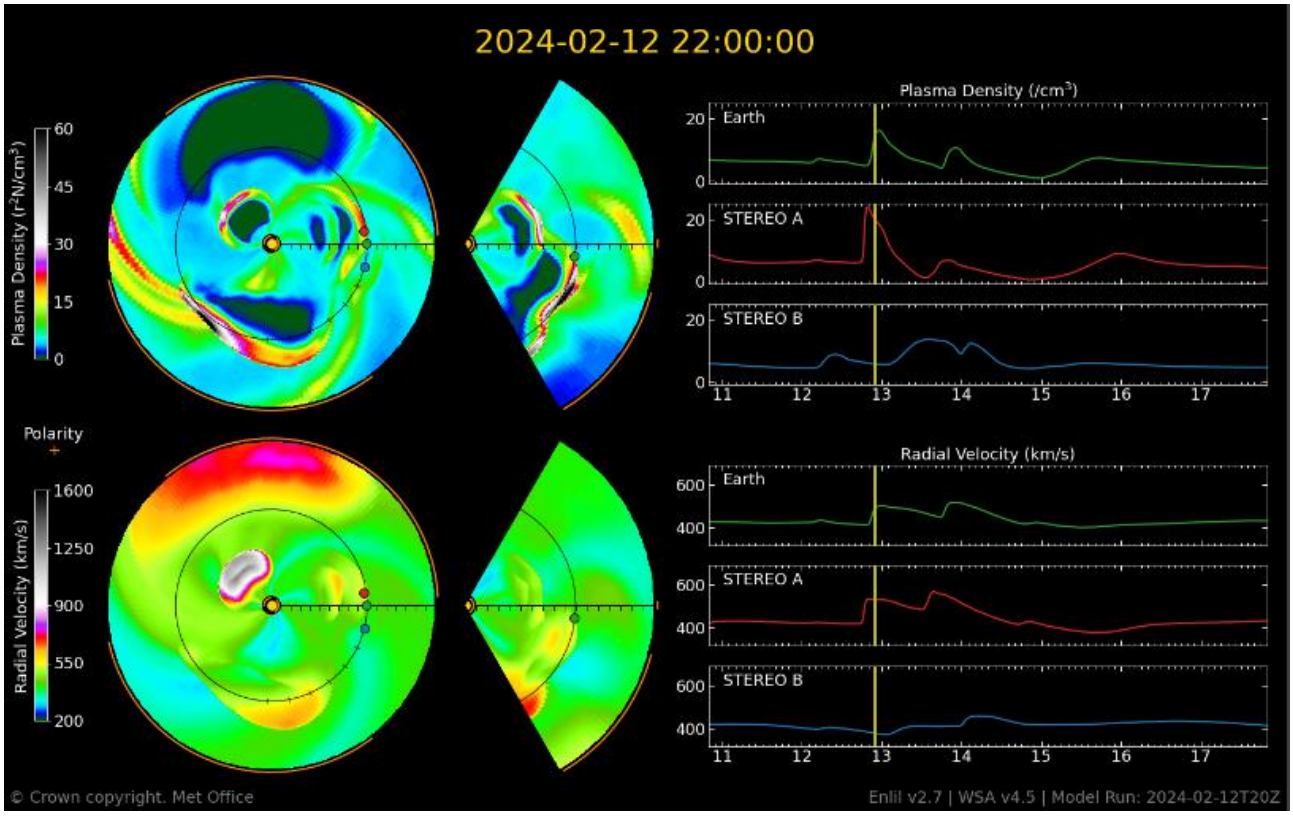
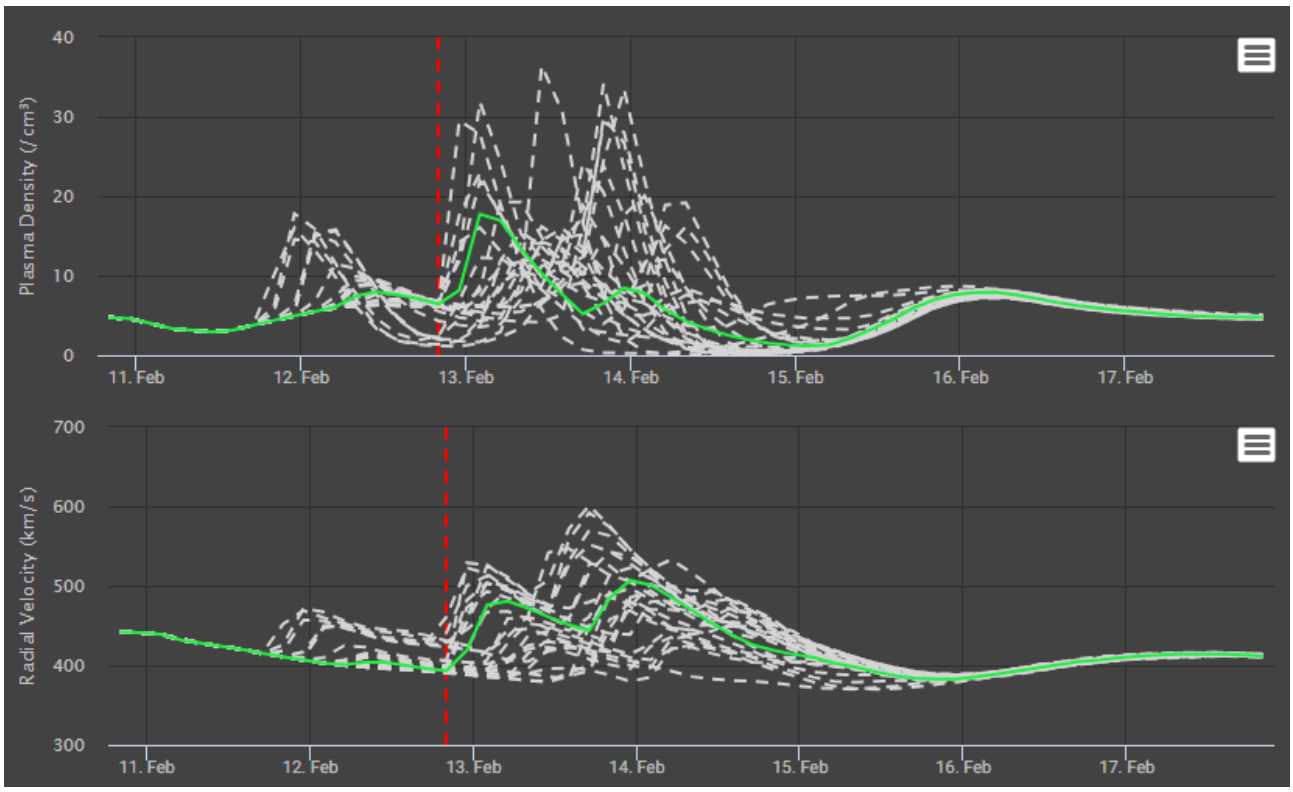
Figure 2: MOSWOC Enlil showing up to three CME arrivals in the next 24-36 hours.





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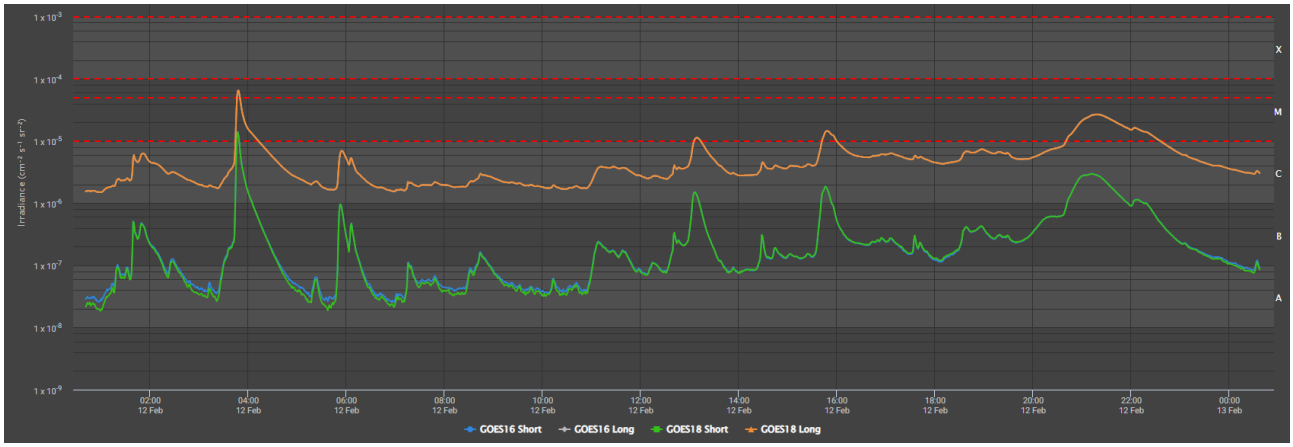
Radio Blackouts - X-Ray Flares:
Solar activity has been Moderate, with a peak flare of M6.5 at 12/0348UTC, originating from AR3576 in the southwest quadrant. A long period M2.6 flare peaking at 12/2117 UTC was also seen from over the northeast limb.

There are seven sunspots on the disc, with AR3579 having faded but a new region has rotated onto the northeast limb. Large region AR3576 continues to be primarily comprised of negative polarity spots, but with a weak delta spot persisting to the north of its main leader. Slow growth has continued in AR3582, with some coalescence in the intermediate spots of AR3583, plus an increase in length. Both these regions have some slight complexity, with a beta-gamma configuration, and hints of a weak delta trying to develop in AR3583. The new region on the northeast limb may be the leader of a larger region, with flare and CME activity evident from over the limb.

Further M-class flares are expected, mainly from AR3576, but with an increasing potential from the new region over the northeast limb, and perhaps from AR3582 or AR3583. There is now a chance of X-class flares, either from AR3576 or possibly the region over the limb.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	80	80	75	70
Very Active	R3 to R5 X Class	No	25	25	20	20

Figure 3: X-ray trace at GOES16 and 18, showing an R2/Moderate radio blackout at 0348 UTC from AR3576, with several R1/Minor radio blackouts, including a recent long period flare from over the northeast limb.



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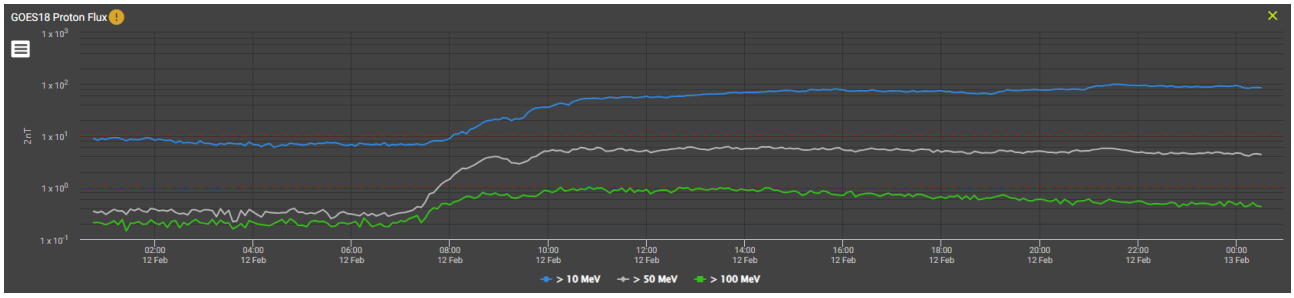
Solar Radiation Storms - (High Energy Protons):
GOES18 high energy (greater than 10MeV) proton flux has become enhanced again following a large far-sided flare and CME eruption from beyond the southwest limb, with the likely source being ex-3575. The S1/Minor Radiation Storm level was breached soon after 12/0800Z and rose to just briefly touch the S2/Moderate threshold at 12/2130 UTC. Further enhancements are possible, either from the potential CME arrivals Day 1 into Day 2 (13-14 Feb), along with any significant flares from AR3576. Ex-3575 is now well beyond the west limb, likely past W150, and as such the risk of further proton storms from this region is declining. In the absence of further enhancements, proton flux is expected to follow a slow declining trend, likely falling back below the S1 threshold Day 2 into Day 3 (14-15 Feb).

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	70	40	20
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Proton flux at GOES18, showing 100MeV proton flux reaching close to the 1pfu threshold, and 10MeV proton flux reaching close to the S2/Moderate storm threshold of 100 pfu.



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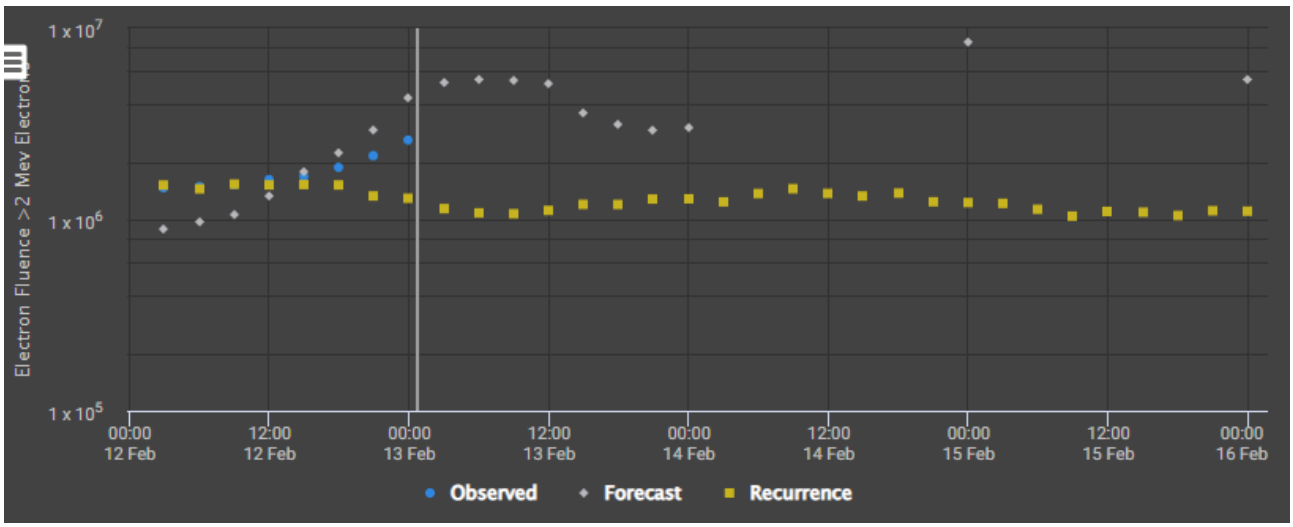
High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) as observed by GOES16 is expected to continue at mainly background levels. There are no coronal hole enhancements forecast, however multiple potential CME arrivals through Days 1 and 2 (13-14 Feb) may drive some increased electron population in the Van Allen belt, but will likely compress the belt inside of GEO. As solar wind pressure eases later in the period, the Van Allen belts are likely to relax back to GEO. This may result in periods of moderate or perhaps high flux.

The associated 24-hour electron fluence is expected to remain well below the Active (1e8 integrated flux) threshold at first, but with the potential for a rising trend later in the period. There is a slight chance of Active fluence by Day 4 (16 Feb). MOSWOC REFM is likely to become less reliable through the period due to the arrival of a number of CMEs.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	5	10
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: MOSWOC REFM showing a fluence forecast well below Active, although it will not be taking account of potential CME arrivals.



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